Technical Documentation to Support Development of Minimum Flows and Levels for the Caloosahatchee River and Estuary

Appendix F

Hydrodynamic and Salinity Modeling

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Contents

Florida Bay and Lower West Coast Division
Southern District Restoration Department

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Summary

The MFL update utilized CH3D hydrodynamic and salinity model and a regression model to investigate the salinity distribution in Caloosahatchee River. The Tidal Caloosahatchee basin model was applied to estimate the ground water and tributary input. The steady state simulation confirmed the previous MFL rule. Under current conditions, the 300 cfs at S-79 is matched by an additional 200 cfs or greater of tidal watershed inflow about 50% of the time. At the steady state, the combined flow of 500 cfs produces a salinity of about 10 ppt at Ft. Myers. An assessment of the recommended CERP alternative indicated that modified flows would create desirable salinity levels at Bird Island and Site 2 for the 2020 with Restudy scenario.

Background

A Minimum Flow and Level Rule (MFL) for the Caloosahatchee River and Estuary was adopted in September 2001. Best available information indicted that a mean monthly flow of 300 cfs at the Franklin Lock and Dam was required to maintain sufficient salinity to prevent a 30-day average salinity concentration exceeding 10 parts per thousand (ppt) at the Ft. Myers salinity station.

A peer review of the technical documentation supporting the rule endorsed the general approach. However, the review panel concluded that the uncertainty in the estimate of the needed freshwater inflows was too large but this deficiency could be remedied by further research in key areas. The statistical approach used by the District indicated that 300 cfs would maintain a salinity of about 10 ppt at Ft. Myers. However, the error surrounding this estimate was large (95% confidence ranged 5.4-17.4 ppt). The panel concluded that the statistical approach was flawed and strongly recommended that a mass balance modeling approach be used in predicting salinity and assessing minimum flows (Edwards et al. 2000). They further suggested that a mass balance model of Charlotte Harbor being developed at the University of Florida be used to refine the salinity simulations for the Caloosahatchee Estuary once it is available (Edwards et al. 2000).

The simulation of Caloosahatchee River MFL update utilized partial deliverables from the above project. The Caloosahatchee River portion of the Charlotte Harbor Model was further calibrated to derive the relationships between the fresh water discharge and the distribution of salinity.

The original technical documentation of the Caloosahatchee MFL concluded that under present conditions, the MFL could not be met. The recovery strategy for attaining the MFL relies on construction projects to be completed by CERP. An additional goal of the modeling effort was to predict the effect of CERP projects on salinity in the downstream estuary.

Modeling Approach – CH3D Model & Regression Model

The salinity model for Caloosahatchee River was developed from a CH3D Charlotte Harbor model (Sheng, 2002), a 3-dimensional fully coupled hydrodynamic and salinity model on

curvilinear grids. The Charlotte Harbor model was calibrated using data collected during the summer of 1986 at 6 stations located in Pine Island Sound and around the Peace River in Charlotte Harbor. The hydrodynamic model was calibrated with a 2 months of data, while the salinity model was calibrated with a 2 weeks of data. The Caloosahatchee and San Carlos Bay portion of the model were not calibrated.

This study calibrated the Caloosahatchee River portion of the model using a 2.5 months period of data, collected every 15 minutes at five stations. Equilibrium relationships between fresh water discharge and salinity in the estuary were derived from a series of steady state simulations. In turn, a regression model was constructed based on these salinity discharge relationships. The regression model was calibrated with a 10-year period of salinity records at Bridge 31 (BR31) and Ft. Myers, as well as a 6-month record at Bird Island.

CH3D model

The CH3D model is three-dimensional and employs curvilinear grids. The model simulates time-dependent circulation in estuaries, lakes, and coastal waters. It solves the three-dimensional equations of motion in a non-orthogonal boundary-fitted coordinate system with given computational domain, initial conditions, and boundary conditions. For the present application to the Charlotte Harbor estuarine system, the model solves the conservation equations for the following hydrodynamic variables: surface elevation, 3-D velocities, salinity, and density. The detailed model equations and description can be found in Sheng (1987, 1989, and 2001).

Description of the grid

The computational grid and bathymetry used for the Caloosahatchee River and Charlotte Harbor estuarine system are shown in **Figure F-1**. It contains 145 by 225 horizontal cells and 8 vertical layers. This grid was generated using a grid generation program originally developed by Thompson (1985). The depth information was based on the raw data obtained from the Geophysical Data System of the National Geophysical Data Center. Bathymetry for navigation channels in San Carlos Bay and the vicinity of Sanibel Causeway were based on the latest data provided by Lee County in December 1999. The depths were converted to NAVD88 datum level with 12 benchmarks near Charlotte Harbor. The model has intensive grids, extending from the north at Charlotte Harbor to the south at Estero Bay. It has eight tributary inflows with four rivers in Estero Bay, 3 rivers in Charlotte Harbor and 1 river in San Carlos Bay. Total grid is about 130,000 with horizontal grids 32,000 and 8 vertical layers. The smallest grid cell is about 100 to 150 m. The model extends to the Gulf of Mexico eliminating the boundary effects (**Figure F-1**).

Figure F-2 is the detailed view of Caloosahatchee River portion and the location of monitoring stations. The bathymetry was modified based on the cross-section profile data from Scarlatos (1988).
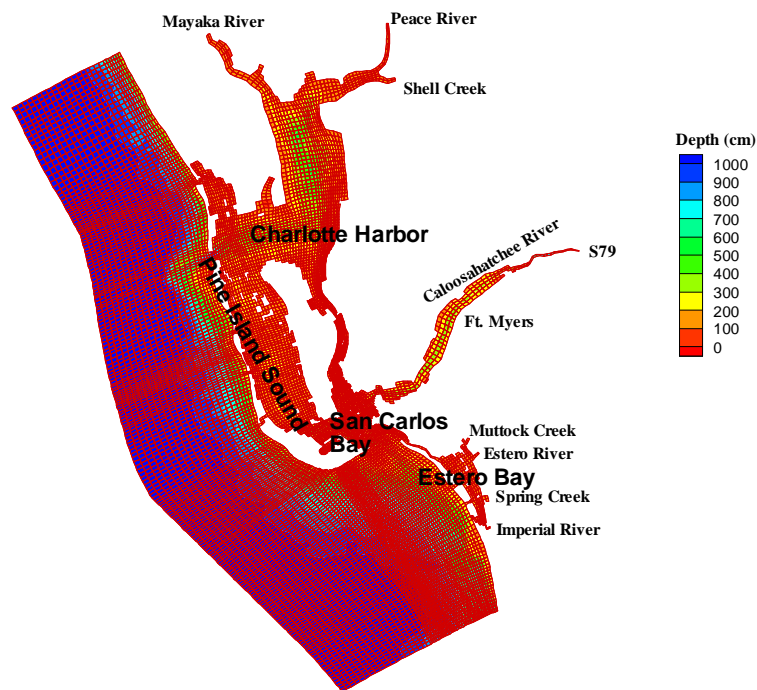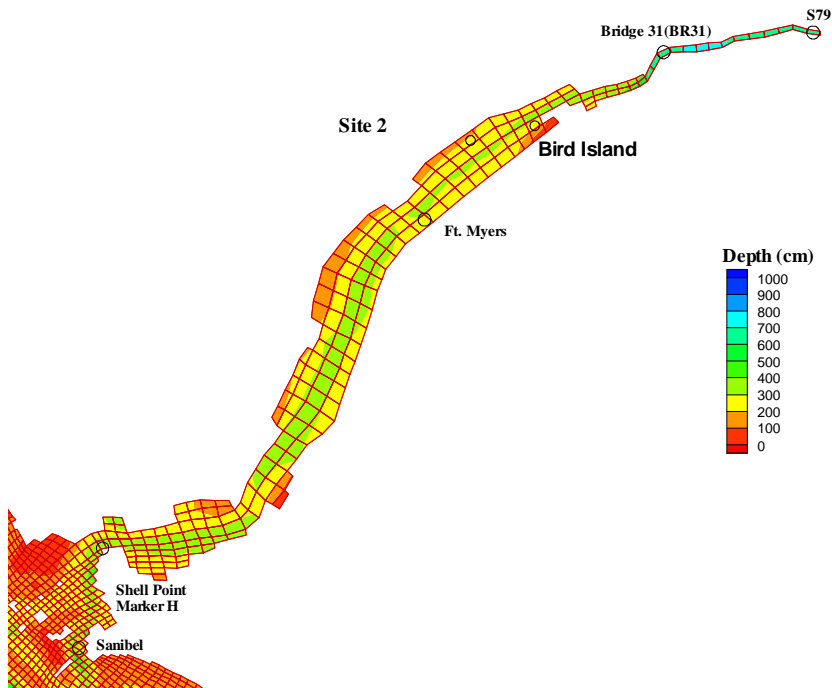
Figure F-1 Computation grid and bathymetry

Figure F-2. Bathymetry on Caloosahatchee River and location of monitoring stations -- **Salinity monitoring stations:** S79, Bridge 31 (BR31), Ft. Myers, Shell Point (Marker H) and Sanibel; **Seagrass monitoring stations:** Bird Island and Site 2.

Model calibration

Description of the calibration scenario

The calibration encompassed the dry season period from October 15th to December 31th 2000. The calibration data set was composed of 2 water surface elevation monitoring stations and 5 salinity stations. The water surface elevation stations are located at Shell Point (maintained by the district), and Ft. Myers (maintained by NOAA). Five (5) salinity monitoring stations are located at S79, Bridge 31 (BR31), Ft. Myers, Shell Point (Marker H), and Sanibel. The tidal boundary condition was derived from Shell Point water surface elevation monitoring data. The driving forces included freshwater discharge at S-79, tide, wind, rainfall and evaporation.

Calibration results

Figure F-3 shows the calibration of water surface elevation at Shell Point: the downstream boundary of the Caloosahatchee estuary. The solid line is the model result, and the dotted line is the monitoring data. The modeling results are close to the monitoring data.
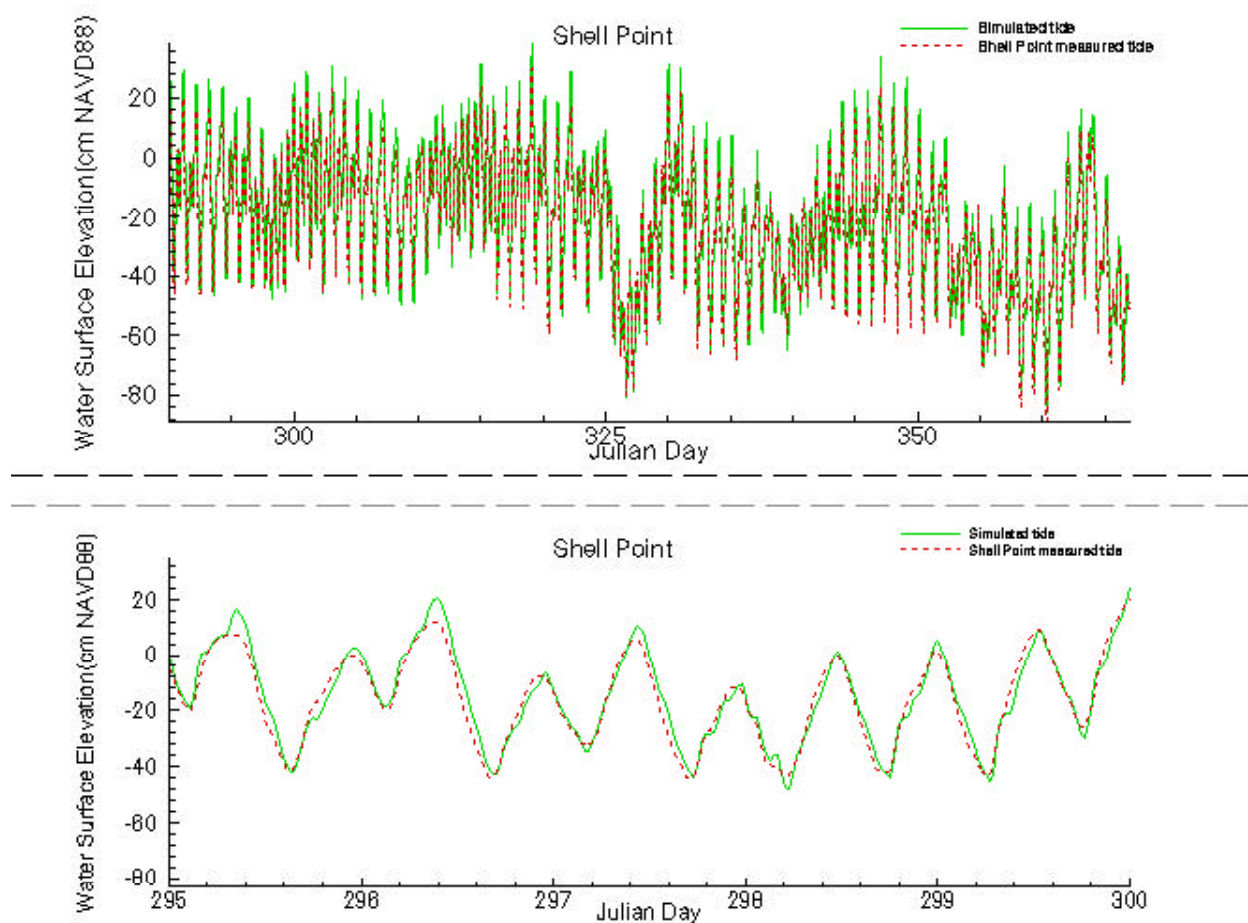

Figure F-3 Water surface elevation calibration at Shell Point (Marker H)

Figure F-4 shows the calibration of water surface elevation at Ft. Myers. This station data reflects the tide upstream on the River. The simulated tide range is close to the real data but a little larger than the real data.
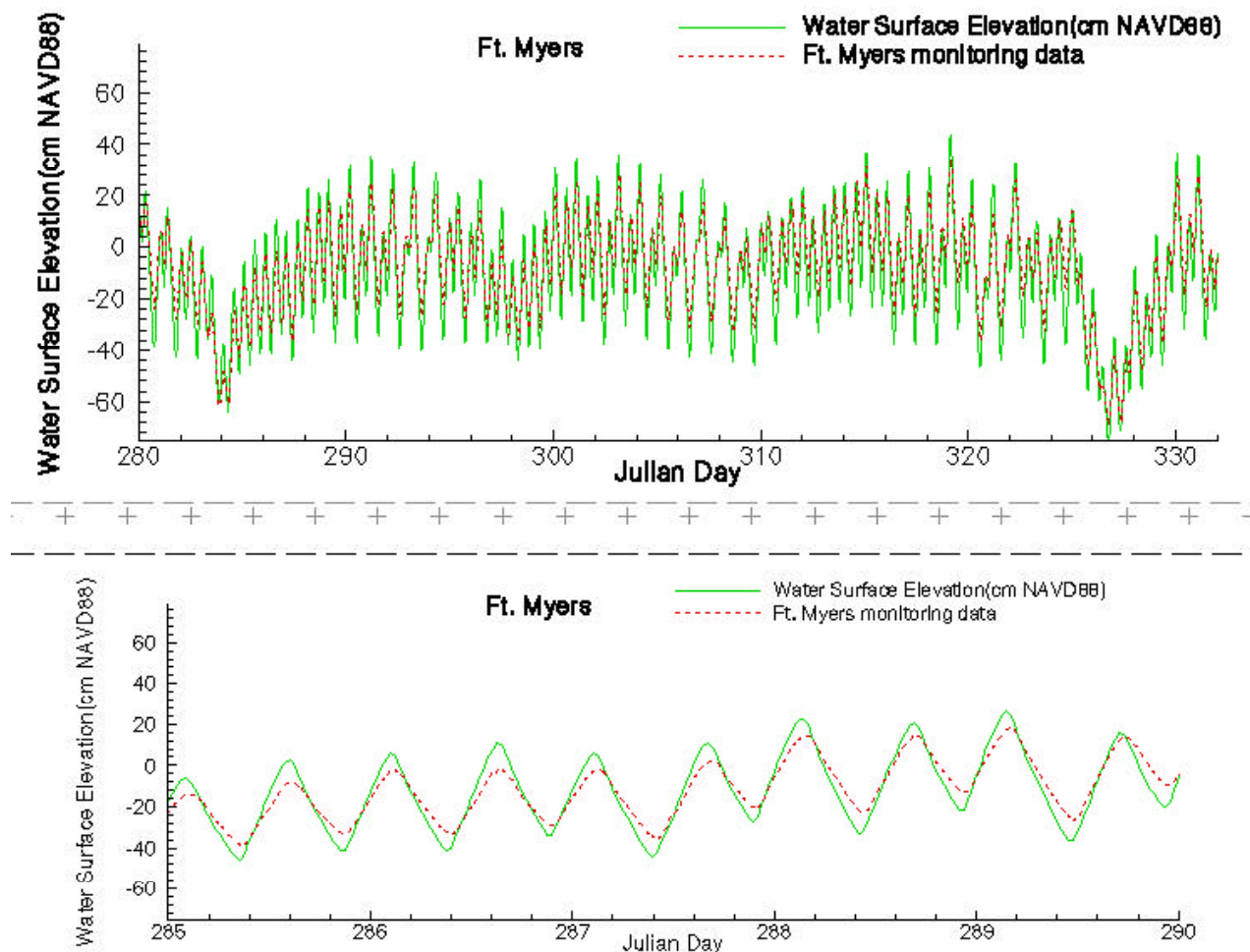

Figure F-4 Water surface elevation calibration at Ft. Myers

Figure F-5 presents the salinity calibration results at S79, down stream of the lock structure, and Bridge 31, located between S79 and Ft. Myers. The thick solid line is the simulated salinity at the second layer from the water surface (25% of the total depth), while the thin solid line is the simulated salinity at the second layer from the bottom (75% of the total depth). The dotted line is the real data at the surface sensor, while the dashed line is the real data at the bottom sensor. In November, the only discharge event was from the 22nd to 26th (Julian days 327-332). So the salinity kept rising until the discharge began.
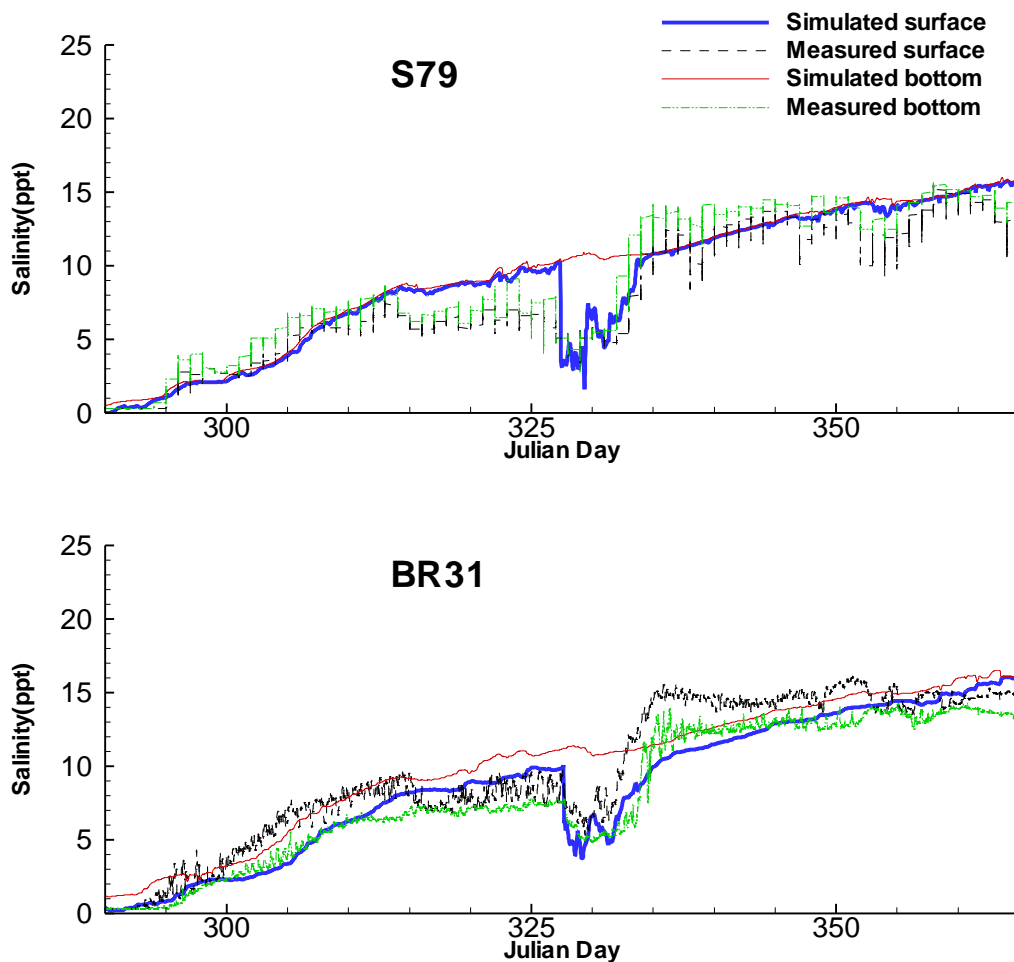
Figure F-5 Salinity calibration at S79 and BR31

Figure F-6 shows the simulation results at Ft. Myers, Shell Point and the Sanibel station in San Carlos Bay. The daily salinity fluctuation range is close to the monitoring data. The model results show good agreement with the monitoring data. At the Sanibel station during a very dry period (December 2000), the salinity in the surface layer was higher than in the bottom layer. The salinity could reach up to 38 ppt. This indicates that evaporation plays a key role in San Carlos Bay. To solve this problem, accurate evaporation data, along with coincident salinity monitoring data in San Carlos Bay and Charlotte Harbor will be needed. It will slightly affect the salinity in the upstream River.
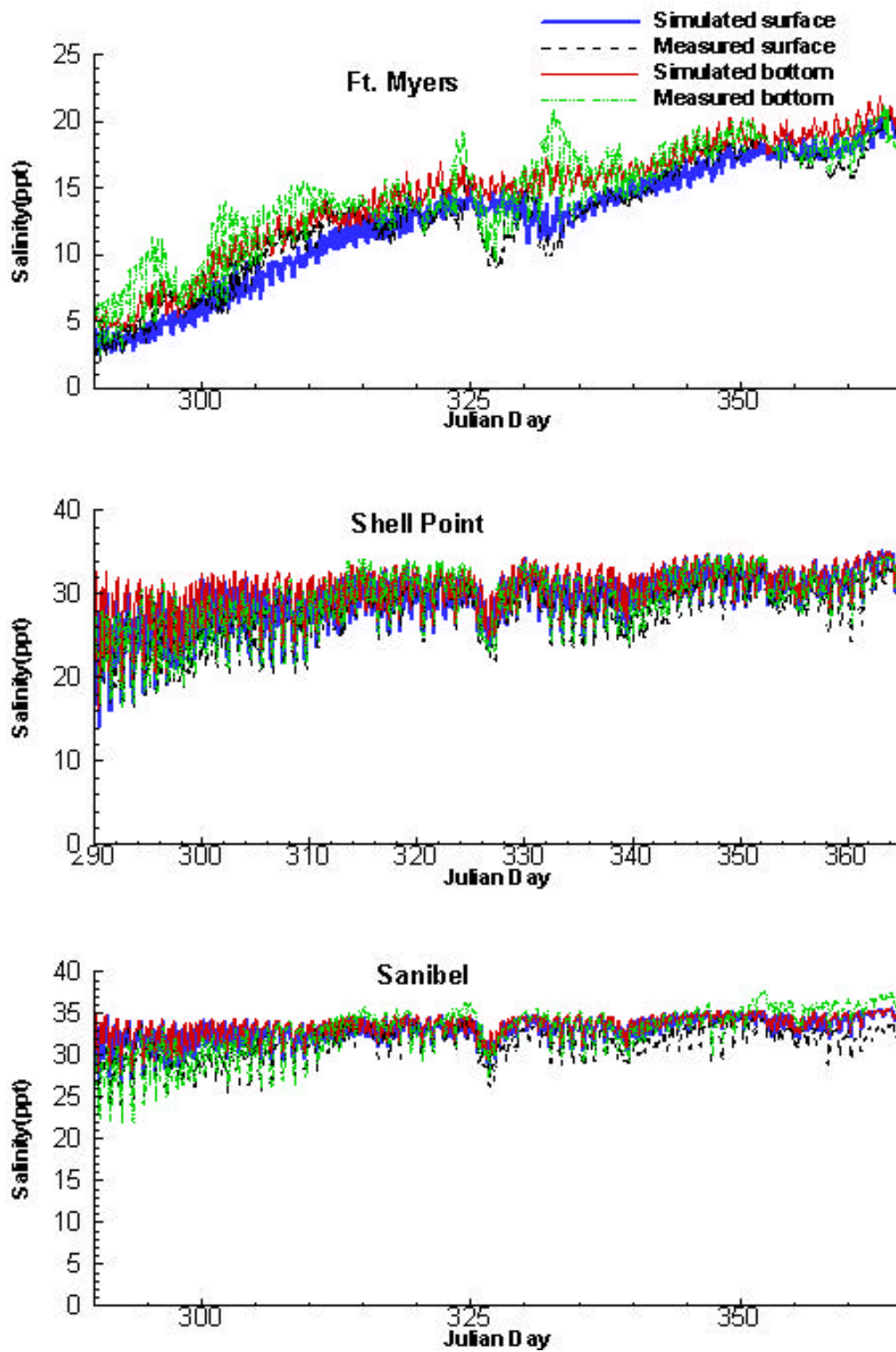
Figure F-6 Salinity calibration at Ft. Myers, Shell Point and Sanibel

Equilibrium relations between salinity and discharge

Based on the calibrated parameters, a group of curves describing the relationships between total discharge and salinity distribution were generated.   Eight (8) scenarios (discharges at 50cfs, 100cfs, 200cfs, 300cfs, 500cfs, 1000cfs, 1500cfs and 2000cfs) were simulated for 40 days. Forty-day simulations allowed the model to reach equilibrium conditions. For convenience, all discharges were simulated as entering at S79; rainfall, evaporation and ground water input were not included as separate variables. The last 10 days of the 40 days simulation results were averaged to obtain the salinity at 4 locations, S79, BR31, Ft. Myers and Shell Point.
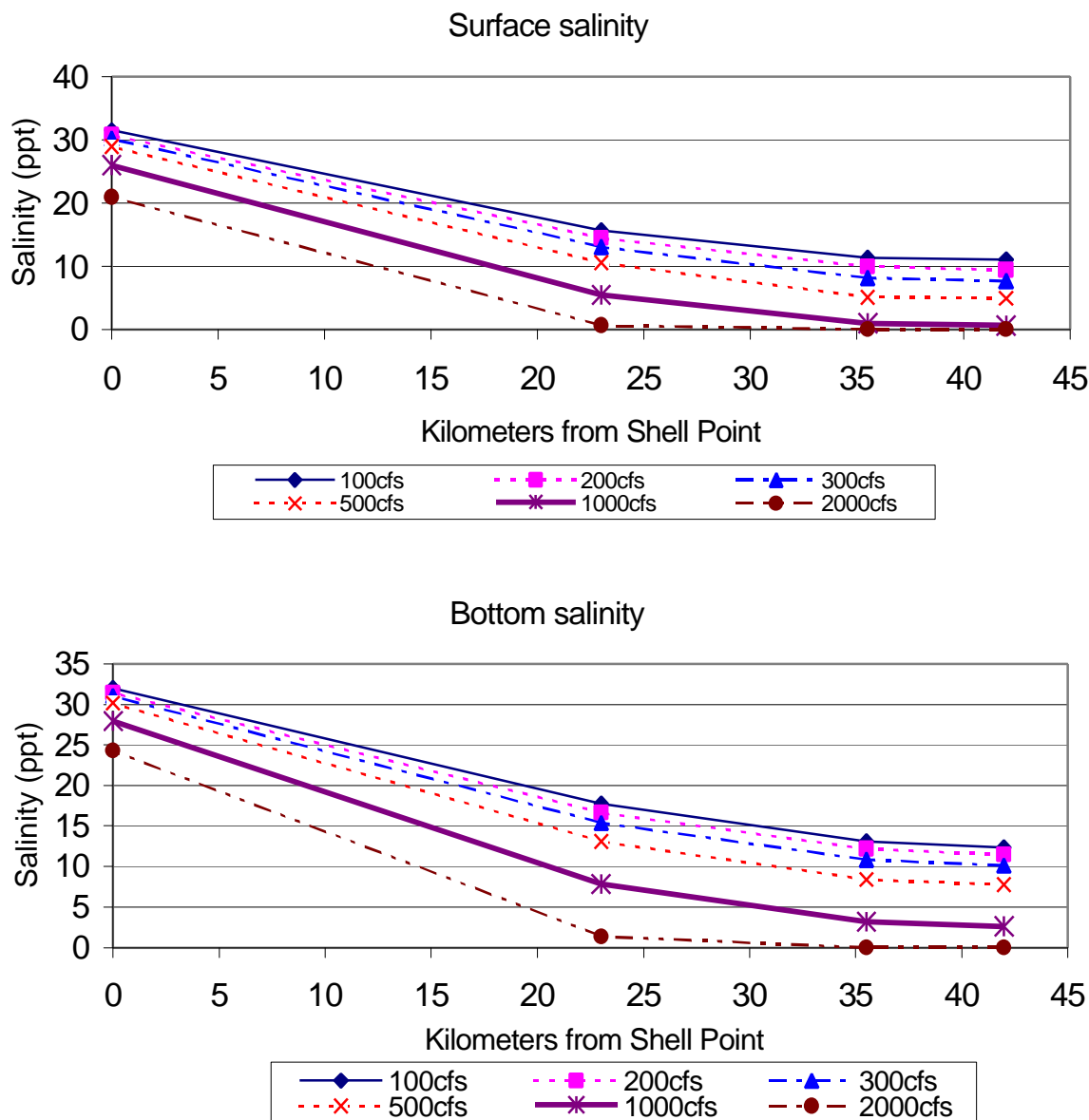

Figure F-7. Salinity as a function of total discharge to the estuary

Estimating total estuarine inflow

The dominant source of inflow to the Caloosahatchee estuary is runoff from the East and West Caloosahatchee Drainage Basin – which enters the estuary at the S-79 structure. However, flows from the tidal watershed are also significant. Previous empirical modeling established relationships between flows at S-79 and salinity within the estuary but specific information on tidal Caloosahatchee flows and direct rainfall and evaporation were only included implicitly in the statistical model through observed salinity data. The hydrodynamic modeling used in this analysis requires explicit knowledge of all waters entering estuary.

Unfortunately, few tidal Caloosahatchee inflows are monitored. However, a watershed hydrologic/hydraulic model has been recently been developed for the Tidal Caloosahatchee Watershed (Peterson, 2002) that can predict tidal inflows. A special simulation of the watershed model was conducted to generate daily estuary inflows by source over the length of the estuary in three years.

Model results were used to develop a characteristic relationship between S-79 flows and total inflows. (Details on the hydrologic assessment are discussed in a separate appendix of the 2002 MFL report.) S-79 flows dominate under high flow conditions while local tidal inflows dominate under low flow conditions. Under current conditions, a discharge of 300 cfs at S-79 corresponds to a total inflow of 500 cfs or greater about 50% of the time. Under current conditions, a mean monthly discharge of 300 cfs would be expected to prevent an exceedance of the 10 ppt criteria about half of the time.

Regression model

The CERP project in the C-43 basin comprises the recovery strategy for the Caloosahatchee MFL. When completed, these projects should supply the supplemental flow required to protect tape grass in the upper estuary.

In the original technical documentation, this proposition was evaluated using two 31 year (1965-1995) estimates of discharge at S-79. These were (1) the common 1995-base case which assumes 1995 land use and current water management operations in the C-43 basin and (2) a future base case (2020 with Restudy) which includes predicted 2020 land uses and the majority of CERP projects in the C-43 basin (reservoirs, aquifer storage and recovery wells (ASR), and back pumping).

Sine the hydrodynamic model cannot be run for 31 years, a regression model was developed to generate a 31-year record of salinity over Vallisneria beds at 2 stations in the upper estuary. The stations are in the 640-acre area to be protected by the MFL and Vallisneria has been monitored at these sites since 1998. The sites are referred to as Bird Island (upstream) and Site 2 (see **Figure F-2**).

A regression model was constructed and calibrated at Ft. Myers and Bridge 31 where 15-minute of salinity data were monitored. The salinity at Bird Island and Site 2 (**Figure F-2**) were interpolated with the salinity results from regression model at Ft. Myers and Bridge 31.

The spatial interpolation of salinity at Bird Island and Site 2

Since 1998, the District started seagrass sampling at Bird Island and Site2 monthly. During each monthly sampling event, salinity was taken from Hydrolab reading. In addition, the District started monitoring salinity data at Bird Island at 15-minute interval since December 2001. To get the interpolation parameters at Bird Island and Site 2, 15-minute of salinity data at Ft. Myers and Bridge 31 were averaged daily to obtain daily salinity variation. Then, the spatial interpolation was conducted to fit the monthly sampling data at Bird Island and Site 2, as well as a 6-month daily salinity data at Bird Island. The interpolation results are presented in **Figure F-8** and **Figure F-9**. The interpolated salinity data was used for calibration of seagrass model. The spatial interpolation formulae are:

At Bird Island, $S_{Bird\ Island} = 0.2 * S_{Ft.\ Myers} + 0.8 * S_{BR31}$
At Site 2, during salinity increases, $S_{Site\ 2} = 0.6 * S_{Ft.\ Myers} + 0.4 * S_{Bird\ Island}$
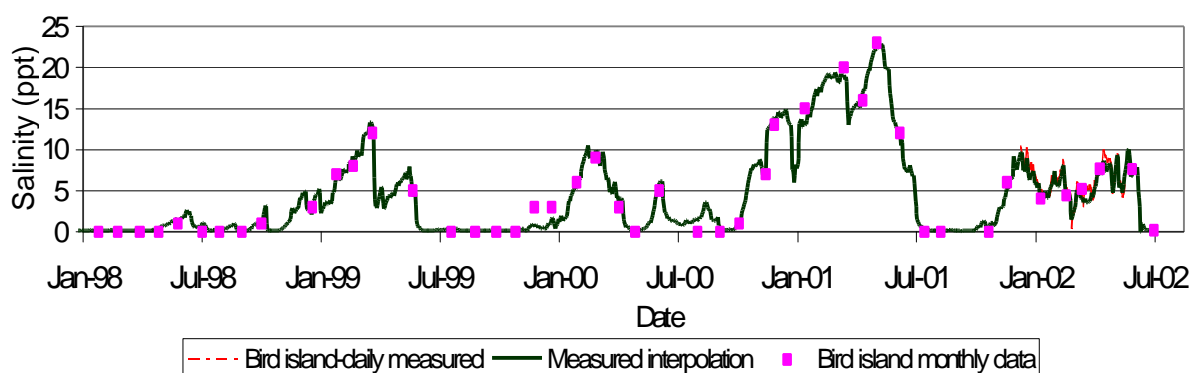during salinity decreases, $S_{Site\ 2} = 0.4 * S_{Ft.\ Myers} + 0.6 * S_{Bird\ Island}$

Figure F-8 Spatial interpolation of measured salinity for Bird Island
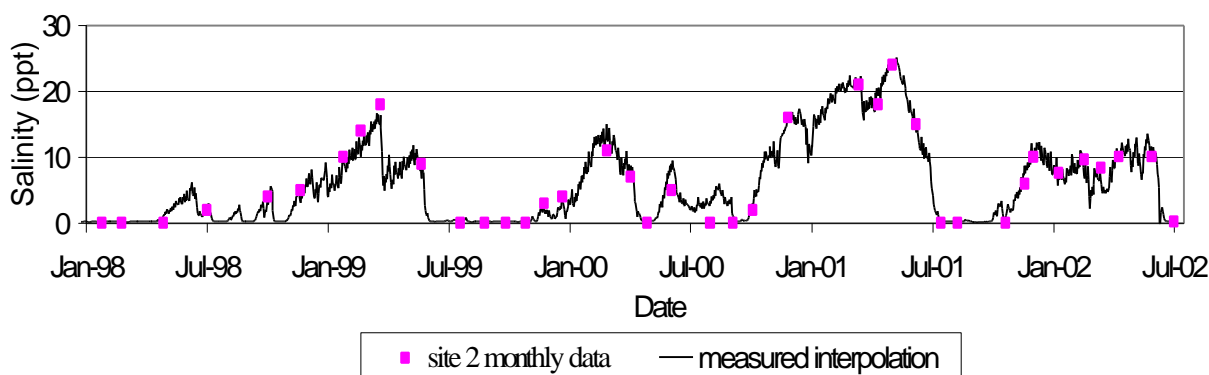

Figure F-9 Spatial interpolation of measured salinity for Site 2

Regression model formulae

The regression model calculated salinity in two steps. Firstly, salinity was calculated from surface layer equilibrium relations between salinity and discharge derived from the steady state simulations with CH3D model. Secondly, salinity was further corrected based on the estuary storage effect and tidal flushing. The total discharge was composed of S-79 discharge, and 50% of total basin runoff and the ground water flow to the entire Caloosahatchee River, since 50% of the tidal basin runoff enter into the River at the upstream of Ft. Myers. The ground water and tributary flow was calculated with rainfall driven formula based on tidal Caloosahatchee hydrology model (Peterson, 2002). Salinity at Ft. Myers station.

At the time step n+1, the salinity at Ft. Myers station (S^{n+1}) was calculated with the following formulae .

$$S^{n+1'} = 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 1300 \text{cfs} < \text{flow}$$
$$S^{n+1'} = 5E\text{-}06*(\text{total flow})^2 - 0.0184* \text{ total flow} + 18.566 \qquad 50 \text{ cfs} < \text{flow} < 1300 \text{ cfs}$$
$$S^{n+1'} = 35 - (35\text{-} 19.5\ )* \text{ total flow}/50\text{cfs} \qquad\qquad\qquad 0 < \text{flow} < 50 \text{ cfs}$$
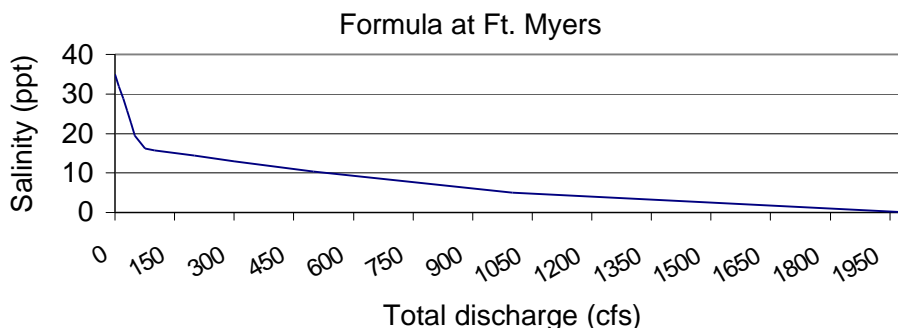$$S^{n+1'} = 35 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{flow} = 0$$

Figure F-10 Formula for preliminary calculation of salinity at Ft. Myers

To include the estuary flushing effect,

$$S^{n+1} = S^n +(S^{n+1'} - S^n)*\text{Ratio\_up} \qquad\qquad \text{if } S^{n+1} > S^n$$
$$S^{n+1} = S^n +(S^{n+1'} - S^n)*\text{Ratio\_down} \qquad\qquad \text{if } S^{n+1} < S^n$$

Ratio_up=0.05,	Ratio_down=0.05	$S^{n+1} < 10$ ppt
Ratio_up =0.03,	Ratio_down=0.02	10 ppt $< S^{n+1} < 15$ ppt
Ratio_up =0.07,	Ratio_down=0.1	15 ppt $< S^{n+1} < 20$ ppt
Ratio_up =0.02,	Ratio_down =0.01	20 ppt $< S^{n+1} < 25$ ppt
Ratio_up =0.012,	Ratio_down =0.01	25 ppt $< S^{n+1} < 30$ ppt
Ratio_up =0.001,	Ratio_down =0.001	30 ppt $< S^{n+1}$

Salinity at Bridge 31 station

At the time step n+1, the salinity at Bridge 31 station (S^{n+1}) was calculated with the following formula.

$$S^{n+1'} = 0 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad 700 \text{cfs} < \text{flow}$$
$$S^{n+1'} = 2E\text{-}05*(\text{total flow})^2 - 0.0297*\text{total flow} + 15.223 \qquad 50 \text{ cfs} < \text{flow} < 1300 \text{ cfs}$$
$$S^{n+1'} = 35 - (35\text{-} 15\ )* \text{ total flow}/50\text{cfs} \qquad\qquad\qquad 0 < \text{flow} < 50 \text{ cfs}$$
$$S^{n+1'} = 35 \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad \text{flow} = 0$$
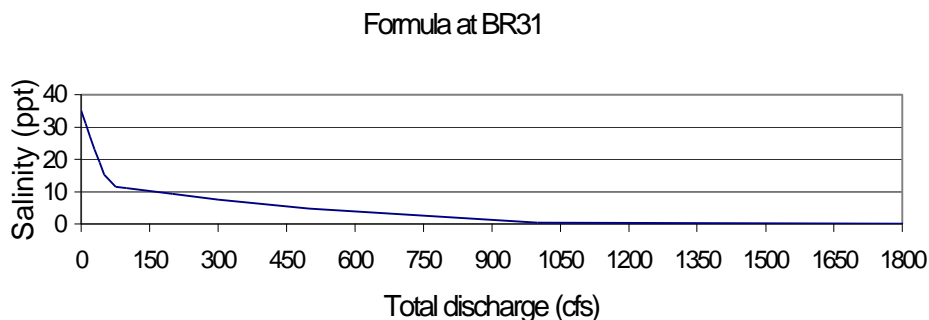
Figure F-11 Formula for preliminary calculation of salinity at BR31

To include the inertial effects of storage and flushing,

$$S^{n+1} = S^n + (S^{n+1'} - S^n)*\text{Ratio\_up} \qquad \text{if } S^{n+1} > S^n$$
$$S^{n+1} = S^n + (S^{n+1'} - S^n)*\text{Ratio\_down} \qquad \text{if } S^{n+1} < S^n$$

Ratio_up=0.02,	Ratio_down=0.03	$S^{n+1} < 5$ ppt
Ratio_up =0.02,	Ratio_down=0.1	$5 \text{ ppt} < S^{n+1} < 10 \text{ ppt}$
Ratio_up =0.05,	Ratio_down=0.01	$10 \text{ ppt} < S^{n+1} < 15 \text{ ppt}$
Ratio_up =0.03,	Ratio_down =0.015	$15 \text{ ppt} < S^{n+1} < 20 \text{ ppt}$
Ratio_up =0.03,	Ratio_down =0.03	$20 \text{ ppt} < S^{n+1} < 25 \text{ ppt}$
Ratio_up =0.0005,	Ratio_down =0.005	$25 \text{ ppt} < S^{n+1}$

If flow > 4500 cfs, $S^{n+1} = 0$

Regression model calibration results

The regression model was calibrated with a 10-year period of daily salinity data at Ft. Myers and BR31. The calibration results are presented in **Figures F-12** and **F-13**.
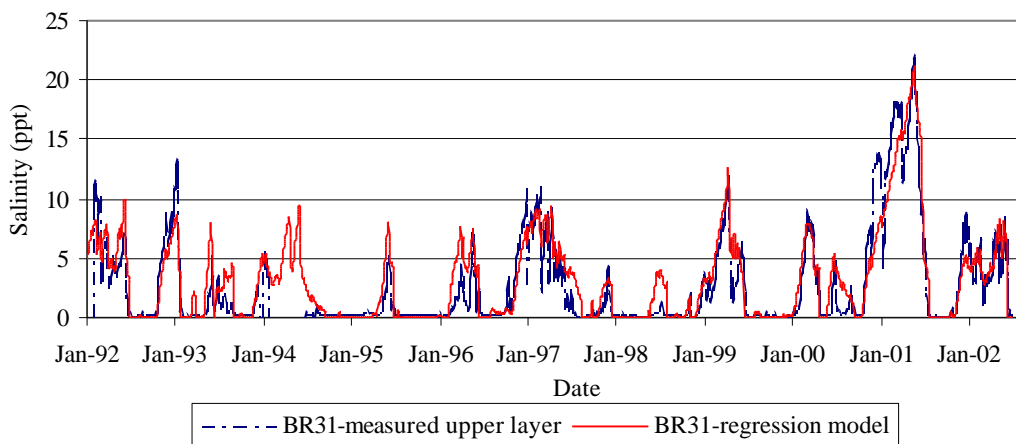

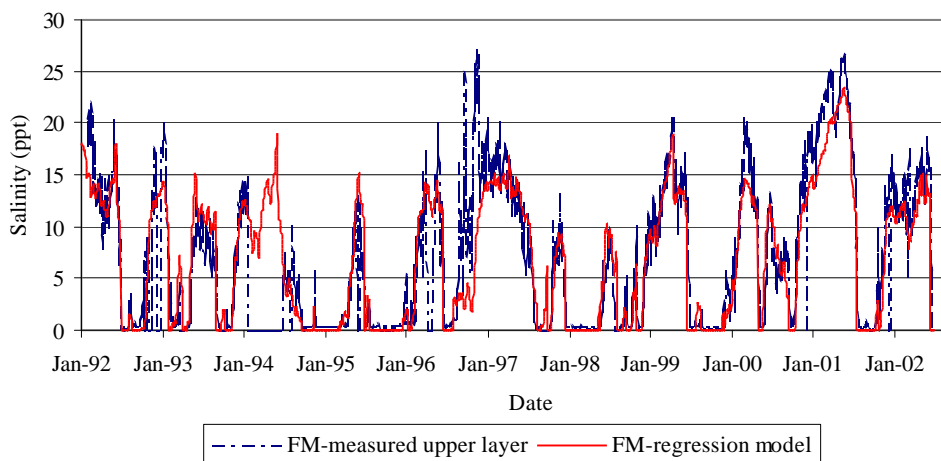Figure F-12 Temporal calibration of regression model at BR31

Figure F-13 Temporal calibration of regression model at Ft. Myers

To predict salinity at Bird Island and Site 2, which lie between BR31 and Ft. Myers, the regression model results were spatially interpolated. The interpolated model results at Bird Island and Site 2 were compared with a 5-year period of monthly sampling data and 6-months of daily salinity data at Bird Island (**Figure F-14**). The regression model under predicted salinity during the period from December 2000 to May 2001. It is due to the large amount of tidal basin runoff predicted by tidal Caloosahatchee watershed model.
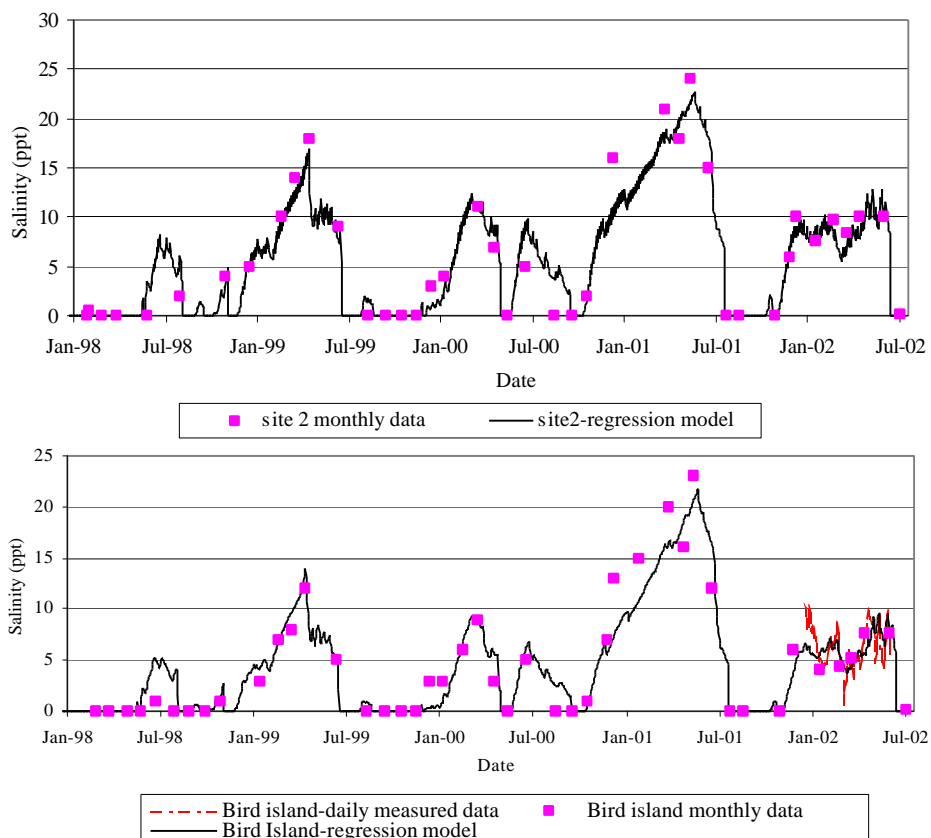

Figure F-14. Spatial interpolation of regression model results at Bird Island and Site2

Assessing CERP: Prediction of salinity for without project (95 base) and with project (2020 with Restudy)

Two scenarios, pre-CERP (95 base) and post-CERP 2020 with Restudy components (2020 with Restudy scenario), were designed by the District to reflect the change of discharge to the estuary due to the CERP projects. The 95 base describing the current drainage basin condition indicates higher peak flow discharge. 2020 with Restudy demonstrates the change of discharge after the completion of CERP projects. In 2020 with Restudy, the storm water is stored in reservoirs and ASR and the fresh water is discharged more evenly with smaller peaks during wet season and larger flow during dry season.

The calibrated regression model was applied to assess CERP project impacts to the salinity variation at Bird Island and seagrass Site 2. The total discharge of these two scenarios are compared and presented in **Figure F-15**. **Table F-1** shows the frequency analysis of the flow discharge under 95 base and 2020 with Restudy. 95 base has 38% of the total flow under 300 cfs. 2020 with Restudy improves the discharge at low flow conditions. The frequency of flow between 300 to 600 cfs has increased from 9% under 95 base to 37% under 2020 with Restudy. Total flow, including discharge from S-79 and flows from ground water and other tributaries, was used as the driving input to the regression salinity model.
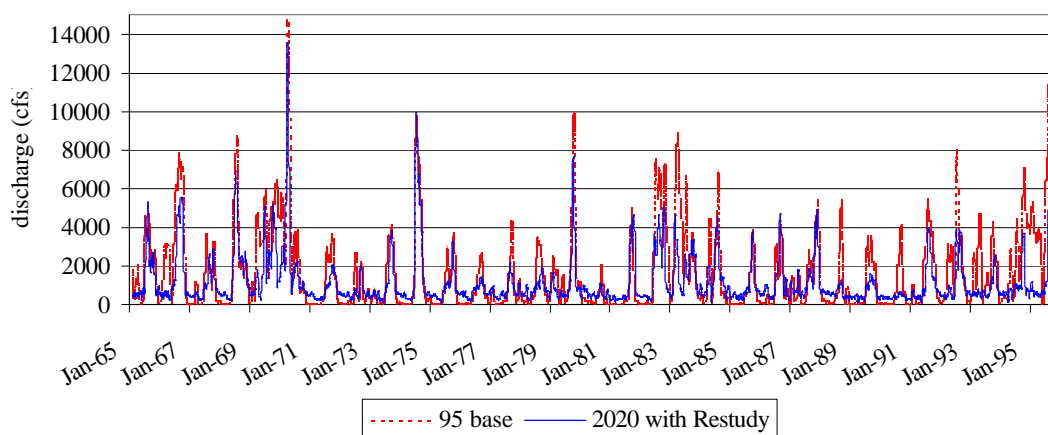
Figure F-15., Comparison of total discharge under 95 base and 2020 with Restudy (30-day moving average)

Table F-1 Frequency analysis of discharge

30 day moving averaged flow (cfs)	95 base total (%)	95 base S79 (%)	2020 with restudy total (%)	2020 with restudy S79 (%)	Ground water(%)
< 300	38	42	6	13	82
300~600	9	8	37	43	7
600~1000	7	7	25	19	6
1000~2500	20	19	19	15	5
2500~5000	18	16	10	8	0
5000~10000	7	7	3	2	0
>100000	1	0	0	0	0

The predicted salinity variations are presented in **Figure F-16** and **F-17** at Bird Island and Site 2 respectively. Both figures show that 2020 with Restudy has lower salinity at the peak than 95 base.

Table F-2 presents the frequency analysis of daily salinity and 30 day moving averaged salinity at Bird Island and Site 2.   At Bird Island, 27% of the daily salinity under 95 base condition are over 10 ppt, while under 2020 with Restudy only 2% of the daily salinity values are over 10 ppt. At Site 2, 41% of daily salinity are over 10 ppt for 95 base, compared with 14% of daily salinity exceeding 10 ppt under 2020 with Restudy. The results demonstrate that CERP projects improve salinity in the estuary by lowering high peaks.
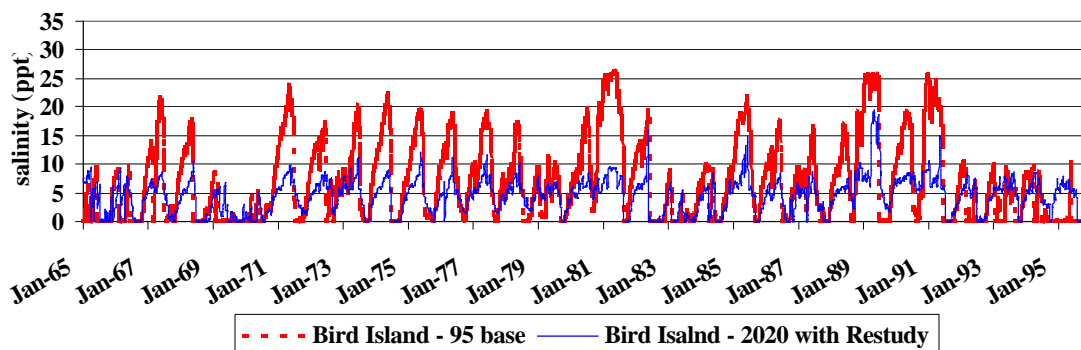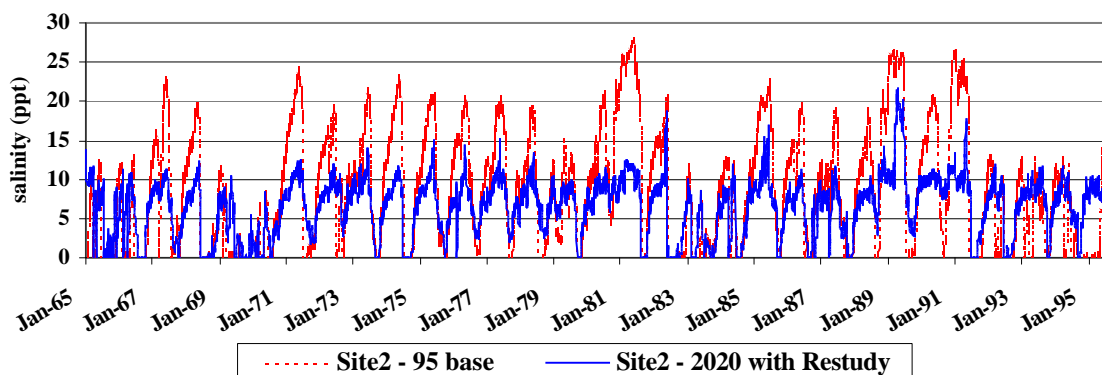

Figure F-16 Predicted salinity at Bird Island

Figure F-17 Predicted salinity at Site 2

Table F-2 Frequency analysis of predicted salinity at Bird Island and Site 2

| salinity (ppt) | Bird Island | | | | Site 2 | | | |
| | 95 base | | 2020 with Restudy | | 95 base | | 2020 with Restudy | |
	daily (%)	30-day moving average (%)	daily (%)	30-day moving average (%)	daily (%)	30-day moving average (%)	daily (%)	30-day moving average (%)
0~5	49	49	53	53	42	41	33	33
5~10	23	24	45	46	17	19	53	54
10~13	7	8	1	1	14	13	12	11
13~15	3	4	0	0	5	6	1	0
15~20	11	10	1	1	13	12	1	1
20~25	4	4	0	0	6	6	0	0
25~30	2	1	0	0	3	2	0	0

Figure F-18 presents the daily salinity and 30 day moving averaged salinity at Ft. Myers. **Table F-3** shows the frequency analysis of the daily salinity and 30 day moving averaged salinity at Ft. Myers. The MFL rule states that the daily salinity at Ft. Myers should not exceed 20 ppt, while the 30 day moving averaged salinity at Ft. Myers should not exceed 10 ppt. For 2020 with Restudy scenario, 1% of the daily salinity values at Ft. Myers are over 20 ppt (Table 2), and 52% of the 30 day moving averaged salinity values are less than 10 ppt. Of the remaining exceedance, 38% are between 10 ppt and 12 ppt. This range of salinity is linked to low flow (300 to 600 cfs) discharge (**Table F-1**). The predicted salinity at Ft. Myers marginally meet the assumed MFL rules, considering the uncertainty in the results. The point where meets the 30 day MFL rule occurs near Site 2 (**Table F-1**), which is 3 kilometers upstream of Ft. Myers, or 2 kilometer from the lower boundary of the protected seagrass area. Of the 31 year period of simulation time, the predicted salinity meet the 30 day MFL rule in three entire years, 1970, 1983 and 1984 (Figure 18). Due to the lack of groundwater input in CH3D calibration, the model might predict the salinity higher than the real values. Continuing work will improve the modeling performance.
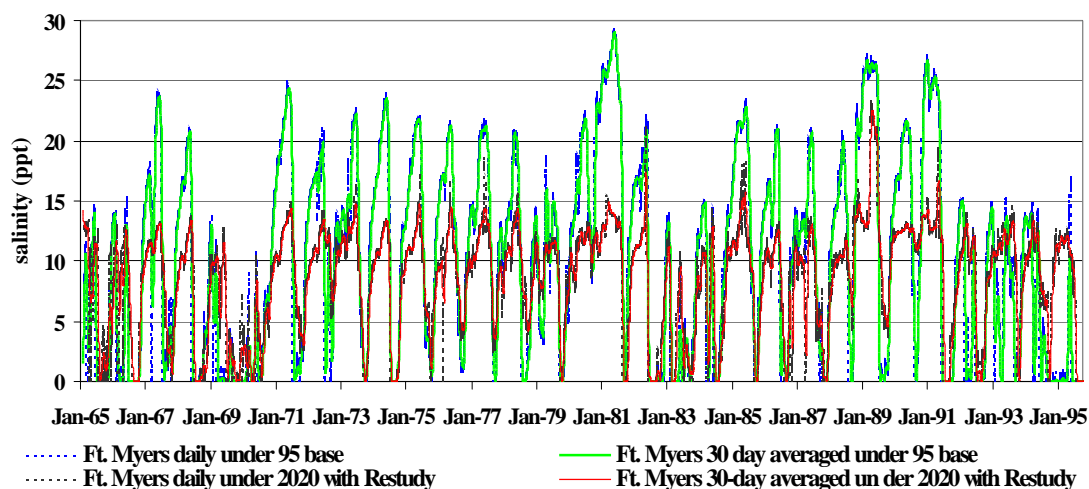

Figure F-18 Predicted salinity at Ft. Myers

Table F-3 Frequency analysis of predicted salinity at Ft. Myers

Ft. Myers salinity (ppt)	95 base		2020 with Restudy	
	daily (%)	30 day moving average (%)	daily (%)	30 day moving average (%)
0~5	37.9	36.7	25.3	24.5
5~10	8.6	12.0	25.1	27.2
10~13	12.5	11.7	39.1	37.6
13~15	12.5	10.9	8.3	9.2
15~20	11.6	13.9	1.3	0.8
20~25	13.4	11.2	0.9	0.7

Conclusions

The CH3D hydrodynamic and salinity model and a regression model based on the 3-D model results were utilized to investigate the salinity distribution in the Caloosahatchee River. The 3-dimensional model was calibrated with a two and half months of data. Then, a series of constant discharges from S-79 were simulated with CH3D model to establish the equilibrium relations between salinity and total flow. A regression model was constructed based on the equilibrium relations. The regression model was further calibrated with a 10-year period of daily salinity data at Ft. Myers and BR31. The regression model results were spatially interpolated to Bird Island and Site 2, and compared with 5-year monthly sampling data. The impacts of the CERP project on salinity variation were evaluated with a regression model based on salinity simulations in a 31-year period.

Under current conditions, a discharge of 300 cfs at S-79 corresponds to a total inflow of 500 cfs or greater about 50% of the time. Under current conditions, a mean monthly discharge of 300 cfs would be expected to prevent an exceedance of the 10 ppt criteria about half of the time. The assessment of CERP project indicates reduced peak salinity at Bird Island and Site 2 for 2020 with Restudy compared with 95 base.

The MFL update incorporated several projects and modeling efforts. The hydrodynamic and salinity model is one of its components. The tidal Caloosahatchee basin model (MIKESHE) was calibrated by Danish Hydraulic Inc. to provide the ground water and tributary flow information to the salinity model. The output of salinity model was used to drive Vallisneria seagrass model to assess the seagrass growth.

The prediction and simulation of these results are limited with data and approaches. No fine resolution bathymetry data exists on the Caloosahatchee River portion, except cross-section profile information. The tidal Caloosahatchee basin model providing ground water and tributary flows needs improvement. 3-d hydrodynamic and salinity model requires further validation with ground water information. The regression model is a simple approach to estimate the estuary flushing and storage factor.

The District is working on several aspects to continue the modeling efforts. The bathymetry survey on the Caloosahatchee River is underway. A grid editing software tool is under contract to be used to edit the existing grid. The MFL salinity prediction will be enhanced with new bathymetry data, the improvement of basin model, and a fast 2-d model with fewer grids to replace the regression model.

References

Edwards, R. E., Lung, W, etc., 2001: Final Review Report, Caloosahatchee Minimum Flow Peer Review Panel, September 27-29, 2000, South Florida Water Management District, pp30.

Konyha, K., 2002: The significance of tidal runoff on flows to the Caloosahatchee Estuary, Technical Memorandum, South Florida Water Management District.

Peterson, M., 2002 (in review): Tidal Caloosahatchee Basin Model, DHI Water & Environment, Technical report to South Florida Water Management District.

Scarlatos, P. D., 1988: Caloosahatchee Estuary Hydrodynamics, South Florida Water Management District, Technical Publication 88-7.

Sheng, Y. P., 2001: Impact of Caloosahatchee Flow on Circulation & Salinity in Charlotte Harbor, Technical Report for South Florida Water Management District, Civil & Coastal Engineering Department, University of Florida, Gainesville, Florida.

Sheng, Y. P., 2001: Users' Manual of a Three-Dimensional Circulation Model for Charlotte Harbor Estuarine System, Civil & Coastal Engineering Department, University of Florida, Gainesville, Florida.

Sheng, Y. P., 1987: On Modeling Three-Dimensional Estuarine and Marine Hydrodynamics, Three-Dimensional Models of Marine and Estuarine Dynamics (J.C.J. Nihoul and B. M. Jamart, Eds.), Elsevier Oceanorgraphy Series, Elsevier, pp 35-54.

Sheng, Y. P., 1989: Evolution of a Three-Dimensional Curvilinear-Grid Hydrodynamics Model for Estuaries, Lakes and Coastal Waters: CH3D, Estuarine and Coastal Modeling (M.L. Spaulding Ed.), ASCE, pp40-49.